RESETTLEMENT ADMINISTRATION

Division of Land Utilization

Region VII

Lincoln, Nebraska

WESTERN WHEATGRASS

and

Its Possibilities for Regrassing Farm Lands in the Northern Great Plains

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December 1, 1935

FOREWORD

This report is a compilation of observations and data relative to the usefulness of western wheatgrass in restoring a forage cover to cultivated land in the Northern Great Plains. It is based on the literature cited, with an occasional insertion of an opinion or interpretation by the compilers. Though the citations do not constitute a complete biliography, they are fairly representative of the available information.

Though western wheatgrass has long been recognized as an important and valuable species in the range country, little work has been done toward determining its possibilities and methods of use under cultivation. It has been considered most from the standpoint of management of native ranges. Most of the attempts to cultivate the grass have been rather abortive, and the problems incident to its domestication have remained, for the most part, unsolved.

The present increasing interest in conservation is resulting in a more critical consideration of the uses of native grasses. The possibilities of reclaiming and protecting land, both by artificial seeding and by encouraging natural reproduction, are receiving greater attention than ever before. Western wheatgrass is one of the most promising native species for such use in the Northern Great Plains. Agronomists and conservationists are beginning to translate the recognition of this fact into action. As a result, the lack of knowledge so evident in the present report probably will be rectified, in part, during the next few years. Despite previous failures, it is possible that western wheatgrass will yet become one of the few domesticated native forage grasses.

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INTRODUCTION

Western wheatgrass (Agropyron smithii Rydg.), also known in some localities as blue stem, is native to the prairie and plains region of the United States. It is one of the most highly valued forage plants of the western ranges. Its failure to have been domesticated has been due in part to its rather erratic seed habits, and in part to a widespread conviction on the part of agronomists that certain commercially available forage plants were generally superior.

The possibility of bringing western wheatgrass into cultivation, or at least using it for reseeding depleted areas in the range country has not been wholly ignored. Recognition by experiment station workers of the values of the grass dates back 20 to 40 years, and it has often been recommended for seeding on range and farm lands (9, 16, 18, 31, 38, 39).* It has been included in the test plots at various experiment stations, and doubtless has been given many private trials as well. The results of the trials range from gratifying success to complete failure. On the whole, the grass has not responded to preliminary tests well enough to arouse widespread interest, or to stimulate the breeding of improved strains.

The increasing public and private consciousness of the fact that much of the cultivated land in the northern plains had best be returned to grass is creating an unprecedented demand for forage plants adapted to the region. Plants are needed that can be established on relatively unfavorable situations with a minimum of expense, and that will maintain themselves with a minimum of care. No known plant fully meets these requirements. They seem to be most nearly approached by crested wheatgrass (Agropyron cristatum), but the seed of that species is at present expensive and far short of the demand. Under these circumstances, it seems probable that western wheatgrass will be useful for reseeding purposes. Though there are but few guiding precedents for artificially establishing the grass, the soils and localities to which it is adapted can readily be determined by observing its natural distribution. On sites to which it is best adapted, it may be expected to yield returns fully as satisfactory as those from the standard cultivated species. Under certain conditions, particularly on alkali soils, it is probably better suited than any other grass likely to be considered.

The present compilation is an attempt to collect and summarize such available information as might be helpful in the culture of western wheatgrass, and in evaluating its usefulness in a program for regrassing submarginal cultivated lands in the Northern Great Plains.

* Numbers in parenthesis refer to "Literature Cited", page 21

HABITS OF GROWTH

Western wheatgrass is a perennial, long-lived, sod-forming species. In the latter respect, it resembles bromegrass (Bromus inermis) and differs from slender wheatgrass (Agropyron pauciflorum (Schwein.) Hitchc., A. tenerum Vasey) and crested wheatgrass, both of which typically are bunch grasses. Western wheatgrass spreads by means of underground rhizomes or rootstocks. Single shoots arise from the rhizomes at intervals of 1 or 2 inches, resulting in a relatively uniform turf. The fact that the shoots normally occur singly, and that the leaves as well as the stems tend to stand rigidly erect gives the impression of an open sod. The interlacing of rhizomes in established stands results in increased density of shoots, but apparently the sod rarely, if ever, attains the compactness characteristic of the sod of bromegrass. Like bromegrass, western wheatgrass is not promptly killed by cultivation. A single cultivation, even as violent as plowing, ordinarily has a rejuvenating effect, and the stand comes back more vigorous than before.

Under favorable conditions, western wheatgrass produces a fairly heavy layer of foliage. The flower stalks, which bear relatively few leaves, attain a height of about 3 feet. Seed are produced in a stout, compact spike, 3 to 6 inches long.

The plants develop rather slowly from seed. Dillman (15) states that the growth and establishment of the seedlings is very slow, and that this constitutes the chief objection to the use of the species for planting purposes. However, crested wheatgrass and brome are not markedly superior in this respect. Slender wheatgrass makes somewhat more rapid and vigorous initial growth. Under moderately favorable conditions, western wheatgrass will produce leaves 6 to 9 inches long by the end of the first season. Flower stalks and new shoots from rhizomes do not ordinarily appear until the second year, and then rather sparsely (31, 35, 37, 38). By the end of the third year, the stand should be thoroughly established, and thickened considerably by vegetative extension. Saunders (38) records that a stand from broadcast sowing "almost covered the ground" by the end of the third season. Stephens (41) states that western wheatgrass planted in rows "soon spread into a solid mat by means of its rootstocks". The period of time implied by "soon" is not specified; presumably it was a matter of 3 or 4 years.

VARIETIES

No record has been found of breeding work with western wheatgrass that has been carried through to the point of yielding concrete results. The need and possibilities of selective breeding with this species have long been recognized (15) and recently, Keim (27) has emphasized again the opportunities in work of this kind. Doubtless, the successful introduction of the species into cultivation will depend on the isolation and propagation of improved strains.

Taxonomists recognize two natural varieties, Agropyron smithii var. molle, and A. smithii var. palmeri. The former, known as hairy wheatgrass, is similar to the type species in habits of growth, distribution, soil requirements, and utility. The latter has a more restricted range, being confined apparently to Colorado, Utah, and southward. No economic significance is attached to the distinction of these varieties.

DISTRIBUTION AND ADAPTATIONS

Distribution. Western wheatgrass is widely distributed throughout the United States except in the eastern and southern coastal sections. It is a common pasture and hay grass on certain soil types throughout its range. It is best adapted to valley bottoms, bench lands, and open plains. It may be found on hillsides and uplands, but tends to give way to the short grasses on the drier situations. According to Hanson (22), it is the most important range species in certain areas of the Great Plains where it is best adapted. He found it to be the only species both frequent and abundant on the range lands near Fort Collins, Colorado. No other plant approached it in either respect; it clearly was the dominant species in the grasslands of that locality. It is said to be the most important native forage plant west of the Sioux Valley region of South Dakota (45). In the vicinity of the Belle Fourche project, South Dakota, it is noted as one of the dominant species of the native vegetation, and with buffalo grass, furnishes the chief forage (16, 30). Cole (12) lists it as one of the three most important species for grazing at Ardmore, South Dakota. Shantz (39) likewise has noted its importance in the western part of the state. In the northwest corner of Nebraska where conditions similar to those in southwest South Dakota prevail, western wheatgrass evidently plays a similar role in the native vegetation. Nelson (31) refers to it as one of the commonest and most abundant native grasses in Wyoming. In North Dakota, Shepperd (40) has reported western wheatgrass as being a secondary species of too sparse distribution to be of much consequence on the native upland ranges, but it is more abundant on moister, heavier soils. Sarvis (38) found it to rank sixth in abundance among the native prairie species in the vicinity of Mandan, North Dakota. Clarke (10) reported this grass as being common on the short grass plains of Alberta and Saskatchewan, but less important than certain other species.

The reports indicate that in general, western wheatgrass attains its greatest importance among native species in western South Dakota, eastern Wyoming, northeastern Colorado, and northwestern Nebraska. Its dominance is relinquished to other species both northward and southward from that region. The obvious inference is that artificial seeding of western wheatgrass will be most likely to succeed in the region of its natural dominance.

Climatic adaptations. The natural range of western wheatgrass is the best indication of its climatic adaptations. Climate alone should not preclude its use throughout the central and northern Great Plains. Various writers have commented on its endurance of drought. Pammel(33)

enthusiastically wrote that "it stands drought in a remarkable manner; the leaves and stems are bright green during the driest weather". Nelson (31) remarks that it withstands drought extremely well. Shantz (39) considered one of the chief adaptations of western wheatgrass to be its ability to revive after desiccation. Dillman (15, 16) found it more drought resistant than slender wheatgrass. Presumably it compares favorably with crested wheatgrass and surpasses bromegrass in this respect though no definite statement to that effect has been seen. Stewart and Gross (42) believe western wheatgrass to rank next to crested wheatgrass in suitability for seeding in northwestern Nebraska. Keim (27) considers it to be even more hardy to western Nebraska conditions than crested wheatgrass.

Drought resistance, of course, is conditioned by the other factors of the environment. The ability of a given species to grow in a relatively dry soil, and to withstand protracted drought without injury diminishes with the departure from its specific optimum requirements of temperature, nutrients, and light. Hence, both the absolute and comparative drought resistance of different species will vary with climatic regions, seasons, and soils. Altitude and latitude, as reflected in intensity of light, density of atmosphere, and length of day may exert a significant influence. Unqualified generalizations concerning the comparative drought resistance of any plant must be regarded as tentative until checked by local experience. There is evidence to indicate that, under certain local conditions in the Northern Great Plains, western wheatgrass is more drought resistant and generally better adapted than any other available plant producing a comparable quality of forage. These conditions involve soil texture, soil salts, and drainage.

Soil adaptations. The local distribution of western wheatgrass in nature is largely controlled by soil type. There is general unanimity of opinion among authorities that this grass is best adapted to moist, heavy, clay and gumbo soils. Under range conditions, it is reported as occurring in pure stands only on soils of this type. It occurs in mixture with other native species on medium soils, and gives way to the latter as the soil type grades from heavier to lighter.

Clarke (10) has recorded the distribution of this grass in Canada in relation to soil type and other grasses. He found that:

1. On loam or sandy loam soils western wheatgrass is present, but less common than blue grama (Bouteloua gracilis), June grass (Koeleria cristata), or needle grass (Stipa comata).
2. On clay soils western wheatgrass predominates and may occur in pure stands.
3. On eroded or silt covered areas western wheatgrass was the principal species.
4. On eroded and weedy abandoned fields of suitable soil type, western wheatgrass is the first important forage grass to become established.

Shantz (39) found it to be best developed on soils of the adobe type, such as are common in southwestern South Dakota and northwestern Nebraska. He found that it is supplanted by wiregrass (Aristida spp.) on soils intermediate between the adobe clay type and sandy ones. Dillman (15) found that western wheatgrass was especially common on the gumbo type of soil in western South Dakota. It was present in thin scattered stand with other grasses on upland soils, and dominant on the lower slopes and in creek bottoms. Pure stands occurred in areas of poor drainage or where some run-in was received. In the vicinity of Belle Fourche, South Dakota, Martin (30) found that it was confined to the lower slopes and bottoms on soils of the gumbo type. The upper slopes and ridges supported less western wheatgrass and more buffalo and grama grasses. Excellent stands occurred on lands subject to over flow. In the San Luis Valley in Colorado, Hanson (20) considers western wheatgrass as an indicator of moist, deep, clayey soils. The frequency and abundance of the species are directly correlated with the soil type and the moisture relations. On drier situations and on sandy or gravelly soils, western wheatgrass gives way partly or entirely to other species.

Aldous and Deeds (2) have recorded the distribution of western wheatgrass by counties and soil types in Montana, North Dakota, South Dakota and Wyoming. They find that it gives way to other native grasses as the soil becomes gravelly, sandy, thin, or loamy, and that it is best developed on the clayey, gumbo type.

Though somewhat toler ant of poor drainage and high water table, western wheatgrass can not endure prolonged submergence. Nelson (31) notes that wheatgrass me adows in Wyoming have been destroyed by too much irrigation.

Probably the most significant adaptation of western wheatgrass relative to its use in the Northern Great Plains is its tolerance of soil alkali. It surpasses all the commonly cultivated forage plants in this respect. Some other native plants are more alkali tolerant, but furnish an inferior quality of forage. Among these may be mentioned salt grass (Distichlis spicata), alkali sacaton (Sporobolus airoides), and the salt bushes (Atriplex spp.). Western wheatgrass makes entirely normal growth on soils containing not more than 0.65 per cent of alkali salts (by dry weight). It will flower and produce seed in the presence of 1 per cent alkali, and will make fairly satisfactory vegetative growth where the salt content is as hi gh as 2 per cent (26). Practically all the more tolerant cultivated plants, such as bromegrass, slender wheatgrass, and sweet clover, are limited to soils with a salt content well under 1 per cent.

These data on soils indicate that western wheatgrass can be established most succesfully on the heavy soils of bottoms, lower slopes, and benchlands. On soils of this type subject to erosion, overflow, and run-in, or that contain much alkali, this grass may prove to be

more useful in establishing a forage cover than any other available species.

It is entirely possible that seeding western wheatgrass on lighter soils will give a stand if moisture conditions are not too unfavorable. The evidence of the natural vegetation indicates, however, that such a stand would not maintain itself against the invasion of plants better adapted to the situation. Grazing would be expected to accelerate the deterioration of the wheatgrass, and favor the invasion of weeds. These observations do not preclude the possibility of extending the natural range of western wheat grass by artificial seeding and regulated grazing. However, attempts to do this will in general be without successful precedent, and should be undertaken at first on a small, experimental scale.

The sandy character of the soils of the project area in southwestern Kansas would seem to eliminate western wheatgrass from consideration for that region. Aldous (3), in a recent survey of the project area, does not report its presence in the native vegetation. The fact that the species is found locally throughout the western part of the state (13, 23) indicates that the soil type is the controlling factor. Western wheatgrass would appear to be equally unsuited to the sand hills of the Sheyenne River project in southeastern North Dakota.

CULTURE

Inasmuch as experience in growing western wheatgrass under cultivation is very limited, the remarks concerning its culture are somewhat sketchy. Certain principles of general applicability are included.

Preparation of the seed bed. It is almost axiomatic that success with the small seeded and slow growing forage grasses depends on careful preparation of the seed bed. With reference to western wheatgrass, Dillman (16) found that a firm, moist seed bed was necessary. Cotton (14) tried seedings of western wheatgrass on the range with and without seed bed preparation. The seed failed to germinate on worn areas on the range that received no preparatory treatment. On comparable areas that had been plowed and smoothed, a fair stand was obtained. Griffiths (18), with reference to range reseeding, states that planting will be successful only when the seeds are covered after broadcasting, and that it is almost useless to sow without some seed bed preparation. However, Knight (28) and Nelson (31) have observed some success after simply scattering western wheatgrass seed over worn spots on the range. Such a procedure is largely a gamble on the weather.

In the cooperative reseeding experiments being conducted by the Northern Rocky Mountain Forest and Range Experiment Station in Montana, grasses are drilled without seed-bed preparation on land formerly farmed, but uncultivated for two or more years. The only treatment is to burn the weeds where the growth is so heavy as to interfere with drilling. It is pointed out by the director of the work that "this absence of soil preparation, in addition to being economical, has the further advantage of preserving most of the valuable native forage plants which may have

become established since the soil was last cropped" (25). Preliminary results indicate a fair amount of success by these methods, particularly with crested wheatgrass. Western wheatgrass has not been included in these trials, but in all probability, it would respond equally well on suitable soils if good viable seed were used.

The later and more conclusive results of these experiments will be most significant. At present, the economic feasibility of seeding formerly cultivated land without seed-bed preparation is very uncertain. If this is shown to be a practical method, it will greatly accelerate the work of regrassing such areas.

Time of seeding: No data are available from which the best date for seeding western wheatgrass in any part of the region may be determined. At Scottsbluff, Nebraska (29) it was successfully planted in the spring (May 31). It seems to have been seeded with equal success at this location in the fall. Dillman (16) had good results from spring seedings at the Belle Fourche project in western South Dakota. He also cites experiements started in 1910 (15) to determine whether this grass could be best planted in fall or spring. No conclusions could be drawn at the time of publication, and no later discussion of this work has been found. Griffiths (18) and Dillman (16) emphasize the value of selecting a seeding date when moisture conditions are favorable. Their plantings usually were successful only when rainfall was timely.

In the above-mentioned reseeding experiments in Montana (25) , plantings are being made both in the fall (October or November) and in the spring (April or early May) . Fall and spring seedings have been about equally successful so far, and no conclusions in this connection have been published.

Methods of seeding. Apparently, western wheatgrass seed will feed readily through a drill (4, 5), though no report of the actual sowing of this grass with any type of mechanical seeder has been seen. It can, of course, be broadcasted by hand. Dillman (15) made plantings in this manner. Various institutions and agencies are contemplating seeding this species on a large scale in the near future. The results of their experience with different methods will be most valuable.

No specific data are available relative to the advisability of using a nurse crop with western wheatgrass. As a general rule, nurse crops with grasses are not recommended for arid regions, unless their use is necessary to prevent soil blowing. The competition of the nurse crop may be a critical factor, the detrimental effect of which far outweigh the benefits during a dry season. When used, the nurse crop should be removed as early as possible after it has served its purpose.

In a recent short article in the "Dakota Farmer" dealing with pasture improvement, it is stated that "ripe wheatgrass hay may be scattered over the old pastures with very gratifying results" (1). This would seem to apply equally well to the seeding of cultivated land. Theoretically, the wisps of hay should afford some protection to the emerging seedlings in the same manner as the straw or burlap sometimes used on nursery beds.

The practical possibility of seeding small areas with unthreshed grasses has often occurred to the compiler of this report, but rarely is mentioned in the literature. Aldous suggests this method for seeding the bluestems (Andropogon spp.) in the project area in southwestern Kansas (3). These are the only instances known to the writer where this practice is proposed. Inasmuch as some grasses are very difficult to thresh, and threshing, at best is somewhat expensive and inconvenient for the small operator, seeding unthreshed grasses might well merit more consideration. If the hay were scattered in the late fall, probably no covering would be necessary; if scattered in the spring, covering might be effected by discing, or by the trampling of stock, as suggested by Aldous (3).

Rate of Seeding: Very few data are available on this subject. The consensus of opinion seems to be that the percentage of germination of this species is low. If this is true, proportionately larger amounts of the seed should be planted per acre. Dillman (16) in discussing broadcasting for pasture purposes recommends that 30 to 40 pounds of seed per acre be used.

The determination of the rate of seeding should be governed by the necessity of an immediate full stand. Under some circumstances, it may be practicable to seed only for the purpose of introducing the grass into an area. Multiplication of western wheatgrass plants through seeding is a slow process, since three years ordinarily are required to complete the cycle from seed to seed (35). However, the formation of new shoots from rhizomes, which begins during the second year, is a relatively rapid and efficient means of aggression into closely adjacent territory. A thin stand thus will soon thicken to a full cover (38, 41). Since reproduction by seeding is slow, the introduction of the grass into an area should be as uniform as possible. This will enhance the effectiveness of vegetative methods of multiplication. A reduced rate of drilling or broadcasting, or seeding in rows might be employed.

Strip seeding requires, for its best application, a species which promptly produces an abundance of seed that germinate readily, and the seedlings of which become established rapidly. Since western wheatgrass appears not to meet these requirements, this procedure is not advisable.

Depth of seeding: Only general recommendations can be made as to depth of seeding western wheatgrass. The seed is similar to that of crested wheatgrass. It is likely to respond favorably to the same culture. On this basis, seeding to a depth of about 0.5 inches would be indicated. A. E. Aldous, of the Kansas Agricultural Experiment Station, states that he believes most native and all cultivated grasses should be seeded to this depth (4). Work with western wheatgrass is contemplated at this station, and apparently it is planned to seed it at the depth mentioned. However, not all investigators are planting wheatgrasses at these depths. Hurtt (25) plants crested wheatgrass 1 inch deep, and slender wheatgrass 1 to 1.5 inches deep in Montana because of the prevalently dry condition of the top soil.

The depth of planting will necessarily be regulated somewhat by soil moisture conditions. Seed will not germinate in dry soil. However, it is equally true that emergence and establishment of seedlings and their relative vigor are decreased with increased depth of planting below the optimum depth. Within these limits, seed should be planted somewhat deeper if the surface soil is likely to dry to a depth of one-half inch before germination can take place. It is in this connection that proper care in selecting the time for planting becomes important.

Care after seeding: In plantings of any grass for range purposes, it is desirable that the seedlings be protected from grazing at least during the first year, and that grazing be carefully regulated thereafter until the plants are thoroughly established.

Annual weedy plants come to maturity rapidly. Heavy stands of such weeds compete vigorously with grass seedlings, both below and above ground. They make intensive demands on the soil moisture supply and, under conditions of restricted rainfall, may succeed in withdrawing an amount sufficient to retard the growth and establishment of the grass seedlings. These weedy species in thick stands often overtop the slow-growing young grass plants, and so intercept the light as to reduce the radiant energy available to them. The seedlings may not be able to maintain themselves under these conditions. If they do persist, they may be unable to become sufficiently well established to endure the dry weather of the later summer, or to survive the winter following.

Mowing such weedy growths just before blooming is the most effective means of controlling them. The mower should be set high in order to minimize injury to the grass.

Old stands of western wheatgrass tend to become sod-bound. In such cases, marked benefits may accrue from harrowing, discing, or even plowing (11, 18, 31, 45, 46). Cultivation thins the stand and improves the physical conditions of the soil, promoting aeration, water absorption and the formation of humus. New plants arise readily from the fragmented rhizomes, and a stand of increased vigor and productivity results. Plowing and cropping for one year, after which re-establishment of the grass is permitted, has given good results (11, 45). These practices admittedly are impracticable under general range conditions, but may be applicable under some circumstances, particularly to promote seed production.

NATURAL REESTABLISHMENT OF GRASS

In localities where western wheatgrass was prominent in the native vegetation, and where it still persists along roadsides, fence rows, and in pastures, this grass often will reclaim abandoned cultivated land in a few years (6, 45). It is obvious that, where such natural invasion is a possibility, it should be encouraged as the most practicable and economical means of regrassing farm land. All tracts of cultivated land that are to be returned to grazing usage should be carefully examined for evidences of

natural reclamation, both in progress and potential. The latter category would include a consideration of adjacent grasslands as a source of seed, the size and shape of the cultivated tract with respect to the distance between its more remote parts and the natural sources of seed, and the position of natural sources of seed with respect to prevailing winds. No rules can be laid down in this connection; decision to leave a tract undisturbed for natural revegetation can be based only on careful judgement of the particular situation and comparison with similar ones that are in more advanced stages of plant succession.

It has previously been noted that western wheatgrass is not immediately killed by cultivation. How long rhizomes remain alive in the soil under the usual farming practices is not known. It is probable that, in land that has been broken not more than 3 or 4 years, persistent living fragments are a factor in the reversion to grass. Land that has been in cultivation for a longer time probably "goes back" only through the introduction of seeds.

The time required for western wheatgrass to reclaim cultivated land is subject to many variable factors, and cannot be stated with any certainty. When living rhizomes remain in the soil, only a year or two will be necessary. Development from natural seeding is slower. One competent observer, in private conversation with the writer, estimated that 6 or 7 years are required under favorable conditions in southwestern South Dakota and adjacent territory. In comparison with the plains region as a whole, this is unusually rapid reestablishment of grass.

It is true that artificial seeding, when successful, will result in a forage cover in less time than the minimum required by Nature. However, the additional time involved in natural revegetation is compensated somewhat by the inevitable proportion of failures in artificial seeding, and by the elimination of seeding costs. Moreover, a tract undergoing natural revegetation would not be without some pasture value. It could be grazed in the fall after the plants were matured. Such utilization not only would yield some forage, but would be beneficial in the distribution and planting of seed. Hence, it would seem advisable to leave untouched all areas where natural reclamation within a reasonable interval of time is likely, and to devote efforts in artificial seeding to areas where the chances of prompt natural regrassing are more remote.

GRAZING

No accounts of grazing studies with planted meadows of western wheatgrass have been found. Such pertinent data as are available deal with native grasslands in which western wheatgrass is an important constituent. Such information is highly valuable, but it must be recognized that a comparison of yields and carrying capacities of planted meadows with those of the native grassland is not a fair comparison of the species involved. With perhaps rare exceptions, they are not growing under comparable conditions

This point will be elaborated further in the discussion of carrying capacity.

Seasonal productivity. Western wheatgrass does not begin growth as early in the spring as do crested wheatgrass and bromegrass in the same localities. Crested wheatgrass has been reported to antedate the native grasses as much as 1 month (21). Western wheatgrass, however, is one of the first native species to start. At an elevation of 5100 feet near Fort Collins, Colorado, it normally begins growth in the latter part of March (22). At Ardmore, South Dakota, the renewal of growth has varied from March 1 to April 10 in different years. Blue grama grass is reported to start 10 days to 2 weeks later, and buffalo grass sometimes is delayed even longer (12).

A minimum of 3 weeks, and usually, 4 or 5 weeks should elapse after the initiation of growth before the grasses are grazed. Cole (12) has supplied some information on the dates when various pastures were ready for grazing at Ardmore, South Dakota:

	1923	1924	1925
Native grasses	May 16	May 15	April 30
Crested wheatgrass	May 4	April 28	April 27
Bromegrass	May 7	May 1	April 27
Sweet clover	June 28	May 15	April 30

Low spring temperatures suppress the growth of western wheatgrass (22). Hence, growth typically is rather slow during April, and may be retarded during May if relatively cool weather prevails. Because of its temperature requirements, western wheatgrass probably is most responsive to May-June rainfall, whereas crested wheatgrass is more responsive to the earlier rains and the melting snows (32). May and June normally are the most productive months for western wheatgrass. When ungrazed, leaf growth is practically completed in the latter month, and flower stalks begin to appear. Under grazing, growth in mid-summer and fall is largely dependent on favorable conditions of moisture and temperature. Little growth takes place during the hot, dry weather characteristic of mid-summer on the plains. Hanson concluded that temperature and soil moisture are the chief factors influencing height growth. Temperature largely determines the time when growth begins in the spring and influences the rate of growth. Soil moisture is important in limiting the total height growth, and probably modifies the time when leaf growth ceases (22).

Translated into terms of practical utilization, these observations indicate that western wheatgrass is most productive of green pasturage during late spring and early summer. Crested wheatgrass and, to a less extent, bromegrass are productive earlier in the spring; bromegrass and sweet clover are, in general, more reliable for late summer and early fall grazing. Western wheatgrass may be expected to make some fall growth if moisture is present in the soil.

Wheatgrass ranges can, of course, be grazed season-long or year-long by so stocking that an excess of forage is produced during the growing season.

The grass cures well on the ground and is grazed with relish throughout the year (20, 35). However, ground cured forage at best is lower in nutrients than when in the growin g condition. It was found at Ardmore, South Dakota, that "the number of days of pasture from the cured standing native grasses was less than half that from these native grasses when pastured while growing and green" (12). Presumably this decrease in forage value was due to decreased nutrient content, since grasses generally produce more dry matter when allowed to mature than when frequently clipped. Records of the gains made by steers on undergrazed pasture at Mandan, North Dakota, show that the nutritive value of grasses cured on the ground is far less than that of the green growing herbage (40). Hence, the forage should be consumed during the growing season in so far as such utilization is compatible with proper maintenance of the range and with adequate provision for the livestock throughout the year. An ideal arrangement would comprise several pastures of different species composition, each of which made its maximum growth at a different time. By proper rotation, the stock could be provided with green forage of maximum nutritive value from early spring until late fall. The judicious use of crested wheatgrass, bromegrass, sweet clover, and the native grasses should render such an ideal partially attainable even in the arid northern plains. No perennial forage plant, however, will consistently produce pasturage during middle and late summer in this region.

Resistance to grazing and trampling. Western wheatgrass is not highly persistent under close, continuous grazing. One of the first evidences of severe grazing is a reduction in the number of seed stalks produced. Under prolonged overgrazing, this grass tends to be replaced by the short grasses, and ultimately by undesirable weeds. When properly managed to permit adequate accumulation of food reserves in the rhizomes and occasional seeding, the grass maintains itself well, suppresses most weeds, and tends to increase in density. The deferred and rotation system of grazing has given very gratifying results with wheatgrass ranges (20, 22).

Because of the network of roots and rhizomes, vigorous stands are quite tolerant of trampling. The grass is thus well suited to bottoms that are likely to be soft after rains. It serves as an excellent soil binder on lands subject to overflow and erosion.

Carrying capacity and pasture value. Quantitative expressions of carrying capacity must be applied very tentatively to any area and to any year other than the place and time to which they specifically refer. Differences in seasons, sites, and density of stands may introduce marked variations in the productivity of the same species in the same locality. This is exemplified in Hanson's statement that from 10 to more than 50 acres of wheat grass range are required per cow unit per season in Colorado (20).

Grazing studies extending over a period of 16 years at Ardmore, South Dakota, indicate that 8 acres per steer for a grazing season of 4.5 months represents the average maximum carrying capacity of the native ranges. Presumably reference is made to the mixed wheatgrass-short grass type

characteristic of the locality. This rate of stocking results in fairly close utilization of the range, and steers do not make maximum gains. Gains are somewhat better under rotation grazing than under continuous grazing with the same rate of stocking. If somewhat better steer gains are desirable, stocking at the rate of 1 steer to 10.4 acres for 4.5 months, or 23 head per section for year-round grazing is suggested (7).

The work cited above also includes a comparison of crested wheatgrass pasture with the native range over a period of 3 years. The average figures show the crested wheatgrass to be markedly superior in carrying capacity, as shown by the acres per steer and the gains per acre in the following tabulation:

	Crested wheatgrass	Native grass
Length of grazing season (days)	110	114.5
Acres of pasture per steer	6	10
Average gain per steer (lbs.)	186.7	180.7
Average gain per acre (lbs.)	31.1	18.1

This comparative trial covered the years 1932, '33, and '34, which were the 4th, 5th, and 6th years in the life of the crested wheatgrass meadow.

At an earlier date Cole (12) reported some pasture experiments with dairy cows at the same station. In addition to the determination of the acres required per cow, records of the production of milk and butter fat were kept. The value of the nutrients necessary to produce these amounts of milk and butter fat was computed in terms of the monetary value of the alfalfa hay and corn silage that would be required to furnish an equal quantity of nutrients. The values thus obtained are tabulated below:

	Acres per cow	Value of nutrients
Native pasture	4.45 acres for 112 days	$4.43 per acre
Sweet clover	2.70 " " " "	6.63 " "
Bromegrass	3.17 " " " "	6.75 " "
Crested wheatgrass	2.73 " " " "	7.70 " "

In justice to the native grasses, it should be borne in mind that the natural prairie chronically is more or less sod-bound (43). Meadows sown to the cultivated grasses sooner or later reach the same state, and their productivity declines. Rejuvenation by cultivation is a regular practice in growing certain of the domesticated grasses, particularly bromegrass. The fact that cultivation likewise will increase the productivity of wheatgrass prairie (11, 18, 31, 45, 46) indicates the prevalence of the sod-bound condition. Comparative studies of the cultivated grasses nearly always are made while the stands are young and at the height of their productive capacity. When yields of such stands are compared with those of sod-bound native prairie, the superiority of the cultivated species is more apparent than real. The significance of this modifying factor seldom is noted in reports of the comparative productive capacity of native and

cultivated grasses, and seems generally to be overlooked.

Palatability and nutritive value. Authorities almost universally comment on the high palatability and nutritive value of western wheatgrass. Sheep relish the mature foliage somewhat less than horses and cattle, but they take the young growth readily, and are fond of the seed heads (20, 35). In the palatability tables of range plants prepared by the Forest Service, this grass is given the maximum rating of 80 for horses and cattle throughout the northwestern range area. The rating for sheep varies from 40 to 50 in different localities.

It is a common observation that relative palatability of forage plants varies in accordance with the identity and quantity of the various components in the vegetation as a whole. A familiar example is the tendency of stock to graze sweet clover sparingly when an abundance of palatable grass is available, although they take it readily when it is the major source of feed. Thus, despite the fact that the Forest Service assigns equal ratings to bromegrass and the wheatgrasses for cattle and horses, it is a not uncommon observation that stock prefer bromegrass when given a choice.

Aside from the practical observation that livestock thrive on wheatgrass ranges, there are few data concerning the nutritive value of the green pasturage. No analysis of clippings of western wheatgrass have been found in the literature. Many analyses of the grass when near the flowering stage, or later, have been reported. These data, however, belong more properly in the discussion of hay. It will suffice here to note that they show western wheatgrass to rank close to crested wheatgrass and bromegrass and usually, well above slender wheatgrass in nutritive values.

HAY

The hay of western wheatgrass is highly pr ized throughout the range region. Considerable quantities are harvested annually from the natural pure stands growing on bottom lands and other favorable situations. Inasmuch as the lands in the project areas most in need of reseeding comprise the better sites (land formerly in cultivated crops), additional hay meadows can best be procured by conversion of these plowed fields. Western wheatgrass should prove useful for this purpose, through both artificial seeding and natural reversion to grass.

Yields. There are but few definite data concerning yields of western wheatgrass hay. Williams (46) states that yields on dry land may run as high as 2 tons per acre, but usually hay can be profitably cut only on alternate years --- removal of a crop has a depressive effect on the stand from which a year is required to recuperate. The average yield of hay from pure stands of western wheatgrass probably is not far removed from the general average of 1.11 tons per acre reported by Piper (34) for all native hays in the United States. In unfavorable years, yields of this grass doubtless will drop to one-half ton or less per acre, as is true of the more commonly cultivated species.

Palatability and nutritive value. According to the results of comparative analyses of crested, slender and western wheatgrass hays reported by Westover (44), western and crested wheatgrasses are approximately equal in nutritive properties. Slender wheatgrass is markedly inferior, containing only about one-half as much protein as the other two species. T. H. Hopper, who made the analysis just noted, has reported elsewhere (24) an extensive study of the chemical composition of forage grasses. A discussion and tabulation of some of his results also can be found in the report on bromegrass issued by this office. His work confirms the popular opinion that western wheatgrass ranks high in nutritive values; but indicates that the particular analysis quoted by Westover gives an unduly poor impression of slender wheatgrass.

Palatability, general feeding value, and appearance (color and leafiness) are matters of common observation on which stockmen usually have positive ideas, and from which market values largely are derived. The demand for western wheatgrass hay usually is good, and prices may equal or exceed those offered for alfalfa (15). It commonly sells for 2 to 3 dollars more per ton than other prairie hays, and is said to be especially in demand around stock-yards because practically no waste is left after feeding (24). It has appeared on the central hay markets in quantities sufficient to justify the establishment of a separate class in the Federal Hay Standards.

Black and Mathews (8) carried out feeding experiments with cattle on the comparative nutritive values of western wheatgrass, alfalfa, corn silage, and oat straw. The work extended over a period of five years. They show that the opinion held by some stockmen that wheatgrass is "stronger" (more nutritious) than alfalfa is largely a fallacy arising from the fact that cattle will consume more alfalfa than wheatgrass if given the opportunity. Their conclusion is that alfalfa and wheatgrass are of approximately equal value as winter rations, i.e., equal weights of the two hays will give approximately equal gains.

SEED PRODUCTION

Seeding habits. As noted in the discussion of growth habits, three years ordinarily are required to complete the cycle of western wheatgrass from seed germination to the production of viable seed (35, 37, 38). Sampson (35) states that in the southern part of its range the cycle may be completed in two years, and that under very favorable conditions some flower stalks develop the first season. His conclusion is that seed production is limited at best on the western ranges.

Sampson's conclusion is both verified and contradicted by other statements in the literature. Without doubt, seed production by western wheatgrass is erratic in the native prairies. It is the most apparent indication of variations in the environment and in the vigor of the plants themselves. Seed often are produced abundantly in favorable situations, such as bottom lands (16, 18). In dry years, or on drier sites, the amount of seed usually is markedly decreased (16, 20). Seed production decreases with increased alkalinity of the soil (26). The vigor of the plants, as

influenced by their density and previous grazing or mowing is reflected in the seed crop. Apart from these evident factors, certain combinations of circumstances occasionally conspire to produce unexpected results. Thus the season of 1935, though generally below normal in rainfall and preceded by the great drought of 1934, has proved to be an unusually good seed year for this grass (1, 5, 19).

The failure of the species to produce seed consistently in abundance needs to be taken into account in the consideration of the grass for use in a planting program. In favorable years, seed supplies can be harvested from established natural stands. Doubtless, some seed are produced every year by stands in the better locations, and such areas might well be protected in anticipation of future needs. However, a dependable supply of seed probably can be most nearly insured by planting specifically for that purpose on the best sites, and with the best cultural care that local conditions will permit. This may require somewhat different management than for forage production. Experimental evidence is lacking in this connection, but the necessity of conditions above the average is indicated by the fact that seed production is spasmodic in nature, that close grazing and mowing usually result in poor seeding the following year (20, 46), and that growth following cultivation, or on land allowed to "go back" is much better than an old, undisturbed sod (18, 31, 43, 46). Under cultivation, seed production probably would be promoted by irrigation, fertilization, and any cultural treatments that thin the stand and reduce competition. Under certain circumstances, row culture with intertillage may prove feasible.

The seed of western wheatgrass mature relatively late in the season. The date varies, of course, with seasonal conditions, latitude, and altitude of the locality. In the northern plains, flowering attains its peak in July and the seed ordinarily are ripe in early September (31, 35). According to an article in the "Dakota Farmer", this year's seed crop in the Dakotas was ready for harvest in August (5). The writer observed western wheatgrass to be ripe in late August (1935) in the vicinity of Lincoln, Nebraska.

There are no definite data available with respect to yields of seed per acre. The impression gained from the literature and from observations of the grass in nature is that yields are fairly high. Dillman (16) makes the vague statement that 100 pounds of seed were threshed from the amount of western wheatgrass cut in an hour's time with an ordinary grain binder.

Definite statements likewise cannot be made with respect to the viability of the seed. It is rather generally held that the percentage of germination is low (15, 16, 35, 41). The literature contains various records of failure to obtain a stand of western wheatgrass, but in most cases it is uncertain whether the seed or the environmental conditions were responsible. Conversely, Nelson (31) states that the wheatgrasses "take kindly to cultivation", and that western wheatgrass "has been found to come readily from seed".

Both the total yield of seed and the percentage of viability may be adversely affected by certain diseases. Western wheatgrass appears to be somewhat more liable to serious infection by disease than crested wheatgrass and bromegrass. The most destructive of these are ergot and rusts similar to, or identical with the black stem rust of wheat. Though ergot is potentially dangerous to stock, it becomes a factor in that respect only when the grass is allowed to mature. Hay cut at the proper time (just past flowering) will not contain toxic amounts of the fungus.

Harvesting the seed. The seed may be harvested in quantity with ordinary grain harvesting machinery and threshed without difficulty. The concaves of the threshing machine should be set close and the wind reduced to a minimum (5, 6, 16). Small amounts may be collected with a comb seed stripper, or cut and flailed by hand.

Seed supply. Western wheatgrass seed is practically unavailable on the market. Some seed houses list seed under this name, but in most instances, the seed so listed are of slender wheatgrass (Agropyron pauciflorum). Hence, in any extensive planting of western wheatgrass, first attention will have to be given to the collection of seed. The office of the Soil Conservation Service at Ames, Iowa, collected about 400,000 pounds of seed of this grass for their own use during the summer of 1935 (17).

As has already been noted, recent reports indicate that an unusually large crop of western wheatgrass seed was produced this year (1935). It is stated that there was a better growth of grass west of the 100th meridian this season than in many years, and that western wheatgrass was especially prominent and was seeding abundantly (1, 5, 19). An anonymous article in the "Dakota Farmer" (5) comments on the large seed crop, predicts a demand for the seed, and recommends harvesting by the farmers in anticipation of this demand. In view of such publicity, and the activities of government agencies, it is likely that a considerable quantity of the seed was harvested, and that it will be stocked by some commercial dealers.

CONCLUSIONS AND RECOMMENDATIONS

This compilation has tended to emphasize the positive results of the limited experience in cultivating western wheatgrass, and the positive possibilities of its use as deduced from this experience and the habits of the grass in nature. The fact should not be overlooked, however, that this grass is not universally abundant in the native prairies of the Northern Great Plains. It has definite preferences and adaptations with respect to types of soil and water relations. The degree of success in seeding will be correlated with the accuracy with which these adaptations are analyzed and heeded. The most reliable indicator of suitable areas for seeding will be the presence of the species in abundance on similar sites in the immediate locality. Observations should be made of native grasslands in the vicinity, particularly undisturbed areas such as may be found along roads and railroad right-of-ways.

A scarcity of western wheatgrass in the local native vegetation does not necessarily mean that it can not be grown. It probably does mean, however, that conditions there are not optimum for it. Plantings on such areas should be undertaken with an experimental attitude, and at first, on an experimental scale. Vigorous natural stands tend to be confined to bottom lands, and to higher benchlands that are relatively favorable through a combination of soil and topographic factors. The possibilities of successful seeding on the drier uplands, especially where the soils are light, will always be doubtful.

The fact should not be overlooked that the forage values of western wheatgrass have long been recognized, that it has been given a number of trials in view of its possibilities for cultivation, and that the results of these trial generally have been negative (35). The lack of success can not be attributed entirely to poor seed habits. What appears to be one of the fairest tests was made at the Northern Great Plains Field Station at Mandan, North Dakota. However, it should be recalled in evaluating the results that western wheatgrass, though present, is not a dominant species in the vegetation of that region. Also, it should be noted that the soil of the experimental plats is described as a sandy loam. The grass thus was not grown under the conditions to which it is best adapted. The tests comprised comparable plats of crested, slender, and western wheatgrasses, and bromegrass grown in rows. The plat of western wheatgrass was continued for 6 years. It never yielded as much as crested wheatgrass, surpassed brome and slender wheatgrass in only one year, and gave a significantly lower average yield than any of the other species. The conclusion reached from these trials was that "western wheatgrass does not lend itself to cultivation" (41).

These failures need not constitute a discouragement, but in view of the present publicity and plans to utilize western wheatgrass for regrassing sub-marginal lands, and for erosion control, past experiences should not be forgotten. The establishment of this or any other grass is not simply a matter of collecting and sowing seed. Only when the requirements of the species are understood and met, or very closely approximated, will successful results be attained. The determination of sites meeting the requirements of western wheatgrass will be somewhat more certain than with introduced species. Its vigor and abundance in the native grasslands of the vicinity will furnish a reliable guide that should never be ignored.

SUMMARY

Western wheatgrass is a valuable native forage grass of the United States which has not been brought under cultivation. It is a long-lived, sod-forming species, and spreads aggressively by underground rhizomes. It produces an abundance of leafy foliage, above which the flower stalks rise to a total height of about 3 feet.

Western wheatgrass is found over most of the United States except the eastern and southern coastal sections, and also ranges north into the prairie provinces of Canada. It forms an important component of the native

vegetation of the plains region and the western inter-mountain grazing lands, attaining its greatest abundance on the hard lands of western South Dakota, eastern Wyoming, northeastern Colorado and northwestern Nebraska. It is generally regarded as highly drought enduring, but tends to relinquish dominance to the short grasses on the most xeric sites in the northern plains.

It is best adapted to heavy clay soils of the gumbo type, and in nature, pure stands are found only on such areas. It frequently occupies areas of rather poor drainage, and lands subject to overflow and deposition of silt. Though present on uplands and lighter soils, it thrives best on lower slopes, benchlands, and creek bottoms. It is an especially promising species for alkaline soils, surpassing all the commonly cultivated grasses in tolerance of such conditions. Satisfactory vegetative growth will take place on soils containing as much as 2 percent alkali, and essentially normal seed production will occur when the alkalinity is 1 per cent or less. These natural soil preferences are indicative of the sites on which western wheat grass should give best results under cultivation.

Experience in the cultivation of western wheatgrass has been too limited to form any reliable basis for recommendations as to the best cultural methods. Naturally, plantings are more likely to succeed when the seed bed is moist and well prepared. However, it seems reasonable to assume that such a strong native species might be seeded with a fair chance of success with a minimum of seed bed preparation. Trials now in progress in Montana, in which seeds are drilled in land formerly in cultivation, but uncultivated for two or more years, are yielding promising results with crested wheatgrass and several other species. The data obtained should be generally applicable to western wheatgrass, though it is not being included in the trials.

The best time for seeding can not be stated with any certainty. Successful seedings in both spring and fall have been reported. Local and seasonal conditions must be considered. Favorable weather and ample supplies of soil moisture are the most critical factors.

Judging from experience with other wheatgrasses, the seed should be planted 0.5 to 1 inch deep, the greater depth being advisable when the top soil is rather dry. The character of the seed permits the use of a drill, which probably is the most desirable method of planting. Very little data are available on rate of seeding. The opinion is generally held that the percentage of germination is low, and therefore, heavy seedings are necessary to secure a complete stand. Dillman recommended using 30 to 40 pounds of seed per acre. In view of the ability of the plants to spread vegetatively, a full cover might be expected in 2 to 4 years from a thin stand, or from seeding in rows.

Newly planted areas preferably should not be grazed the first season and grazing should be carefully regulated thereafter until the plants are thoroughly established. Clipping the weeds before blooming the first year

probably would be helpful. Wheatgrass range is best maintained by deferred and rotation grazing. The productivity of old sod-bound stands can be increased by cultivation. This may be economically justified under certain circumstances, particularly to increase seed production.

Western wheatgrass ranks high in forage values. When grazed, it supplies palatable and nutritious food for all kinds of livestock. Sheep relish the mature foliage somewhat less than horses and cattle. The species furnishes fairly early spring grazing. Growth usually begins in March, but is slow while the weather remains cool, and ordinarily the grass is not ready for grazing before early May. It commonly antedates the associated short grasses 1 or 2 weeks, but is later than crested wheatgrass and bromegrass. In general, the maximum growth of foliage takes place i n May and June; flowering attains its peak in July and early August. Like crested wheatgrass, it becomes dormant during hot, dry weather in mid-summer, but revives in the fall if moisture is present. The foliage cures well on the ground and provides excellent winter grazing.

The relative carrying capacity of western wheatgrass pasture cannot be stated with certainty. Native pastures of which this species is an important component are generally less productive than planted areas of crested wheatgrass or bromegrass. Such comparisons, however, can not form a basis for more than tentative conclusions, because the conditions of growth are not the same.

Western wheatgrass hay is highly prized throughout the range region. It is leafy, palatable, nutritious, and retains a good color. Equivalent weights of wheatgrass hay and alfalfa have been shown to be of about equal value as winter rations for stock.

The seeding habits of western wheatgrass are rather erratic in nature, and the percentage of viable seed appears to be low. The fact that the species sometimes seeds profusely demonstrates that it hav ample reproductive powers, but that better than average conditions are required. These conditions probably can be determined and satisfactorily provided under cultivation.

No data are available as to actual yields of seed. The date of maturity is relatively late. In the Northern Great Plains, seed are ready for harvesting in August or September. The seed crop may be cut and threshed with the ordinary harvesting and threshing machinery.

There is practically no supply of western wheatgrass seed available on the market. Seed collection will be a necessary preliminary step in any extensive planting of this species. It is quite probable that a considerable quantity of seed was harvested in 1935, and that some of this will be commercially available.

It is suggested that the selection of areas to be planted to western wheatgrasses be governed by the presence of the grass on similar sites in the immediate vicinity. Its absence in the native vegetation probably would

indicate conditions not wholly favorable, and the success of seedings would be doubtful.

It is also suggested that the possibilities of natural reversion to grass be investigated before artificial seeding is undertaken. Where this will take place within a reasonable time, it obviously is the most economical and practicable means of reestablishing a forage cover on cultivated land.

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